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GEOLOGY AND ENGINEERING GEOLOGIC ASPECTS OF THE SOUTH HALF TUSTIN QUADRANGLE, ORANGE COUNTY, CALIFORNIA

1976

CALIFORNIA DIVISION OF MINES AND GEOLOGY

PREPARED IN COOPERATION WITH THE COUNTY OF ORANGE
ENVIRONMENTAL MANAGEMENT AGENCY

SPECIAL REPORT 126

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SPECIAL REPORT 126

GEOLOGY AND ENGINEERING GEOLOGIC ASPECTS OF THE SOUTH HALF TUSTIN QUADRANGLE, ORANGE COUNTY, CALIFORNIA

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Geologists

Prepared in cooperation with the County of Orange
Environmental Management Agency.

1976

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SYNOPSIS OF GEO-ENVIRONMENTAL PROBLEMS

The engineering and environmental geologic problems of the south half of the Tustin 7.5-minute quadrangle are summarized here in order of decreasing importance.

Slope Stability

Unstable slopes are a serious hazard although not the problem here as in nearby areas to the south. Hillsides underlain by siltstones and shales of the Los Trancos Member of the Topanga Formation and the Vaqueros Formation and claystones and siltstones of the Sespe Formation are the most prone to landslide and slump failures. However, care should be taken when developing a slope in which bedding planes are parallel to the slope surface in any of the formations. Rockfall failures are infrequent but potentially damaging to any development below a steep slope exposing resistant sandstone or unweathered diabase.

Seismicity

Seismicity is the most widespread hazard to development. The faults most likely to generate damaging earthquakes in the area are the San Andreas, San Jacinto, Elsinore-Whittier, and Newport-Inglewood. The most severe ground shaking can be expected on unconsolidated Quaternary deposits, especially in areas which have a high water table. Although no Holocene (< 11,000 years before present) fault movement was proven in this study, Pleistocene displacement (< 3,000,000 years B.P.) along a fault near the University of California at Irvine and along the Pelican Hill fault 1 mile south of the studied area has been observed.

Grading and Excavation

Grading and excavation will be difficult in areas underlain by well-indurated sandstone beds of the Silverado Formation and highly resistant breccias and flows of the Paularino Member of the Topanga Formation. Occasional cemented sandstones and coquinas in the Vaqueros and Topanga Formations and unweathered diabase may also present excavation problems.

Mineral Resources

There is a deposit of ceramic clay southeast of Sand Canyon Reservoir that could be lost if the area is developed before the deposit is assessed.

Erosion

Erosion will be a problem on slopes blanketed by loose, unconsolidated material such as slopewash and soil (not mapped in this study). Terrace, alluvial, and landslide deposits of Quaternary age are susceptible to erosion where they form steep slopes.

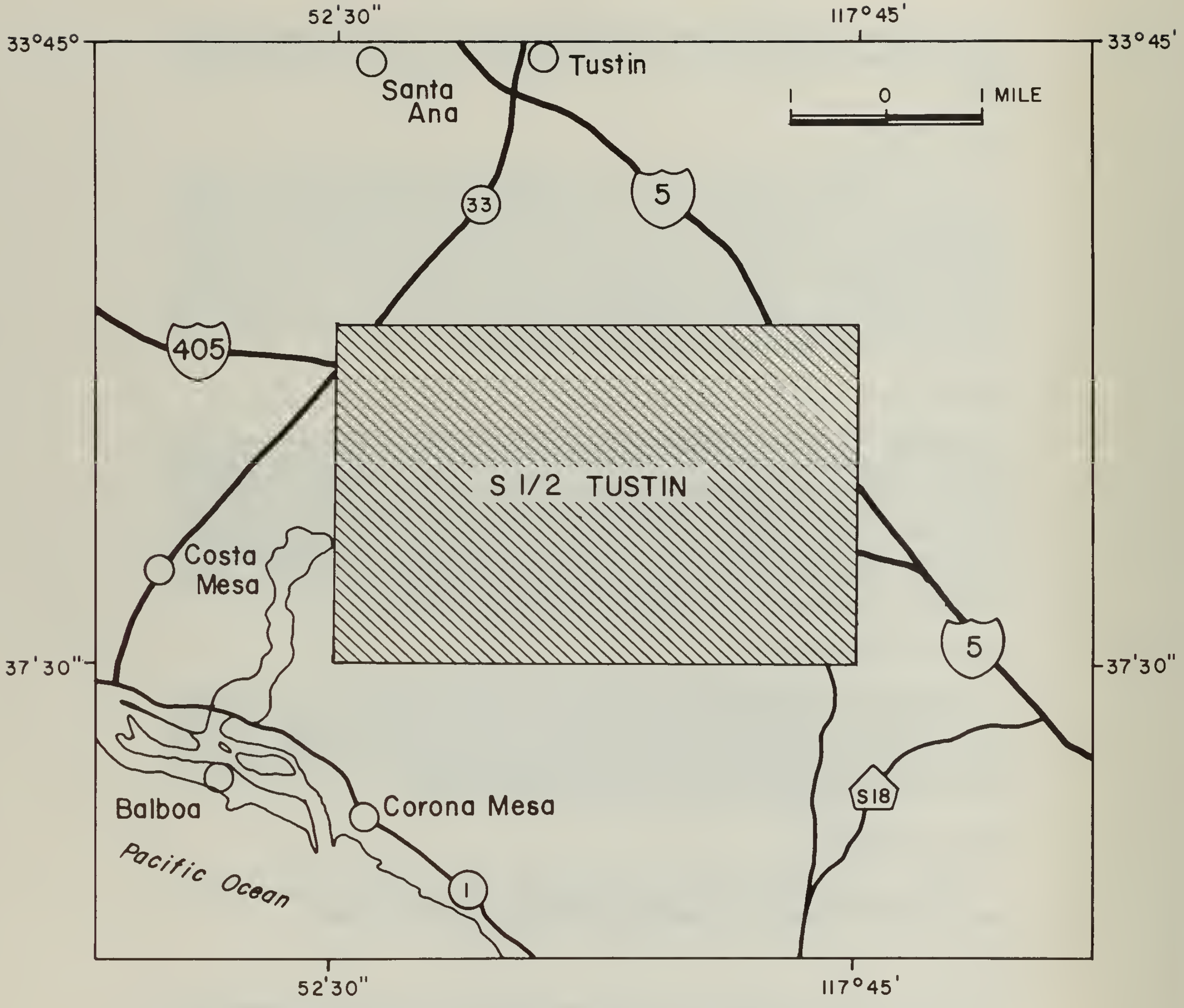


FIGURE 1. Index map

GEOLOGY AND ENGINEERING GEOLOGIC ASPECTS OF THE SOUTH HALF TUSTIN QUADRANGLE, ORANGE COUNTY, CALIFORNIA

By Russell V. Miller and Siang S. Tan

INTRODUCTION

This study was undertaken to provide a basic geologic reference for planning urban development. The resulting geologic map should not be used for the detailed planning of specific engineering structures or as a substitute for detailed site investigations; the map is a generalized regional study delineating geologic features of possible engineering significance. The investigation was done in cooperation with the County of Orange Road Department, Department of Building and Safety, and the Orange County Flood Control District.

Previous mapping of the area by J. G. Vedder, R. F. Yerkes, and J. E. Schoellhamer (1957) of the U. S. Geological Survey was used to determine the bedrock geology. Modifications were made to stress engineering geologic features and to reflect evidence revealed in new exposures.

Geologic mapping of the adjacent area to the east has been published by the California Division of Mines and Geology (Fife, 1974), and the quadrangle to the south is being published concurrently with this report (Tan and Edgington, 1976).

Field mapping for this study was done directly on the U. S. Geological Survey Tustin 7.5-minute quadrangle (1965 edition) topographic map enlarged to a scale of 1:12,000. Aerial photographs flown in 1927, 1939, and 1970 at various scales were studied to augment field efforts, mainly in detecting landslide areas and fault lineaments. The field investigation was done in early 1974, mainly during March and April.

Pacifico Montano of The Irvine Company, John Sayers formerly of Geolabs-California, Inc., John Singer of the U. S. Geological Survey, and Hasu Majmundar and Glenn Borchardt of the California Division of Mines and Geology provided important information, which is gratefully acknowledged. Cooperation of The Irvine Company and other property owners in the area is gratefully acknowledged.

GEOLOGIC SETTING

The south half of the Tustin 7.5-minute quadrangle includes a part of the northern San Joaquin Hills and the adjacent Tustin Plain. The area lies at the southeastern edge of the Los Angeles basin.

The upland areas are underlain by Tertiary bedrock units ranging in age from Paleocene to Pliocene. The distribution of these units is divided by the Shady Canyon fault into a Lower Tertiary (Paleocene to lower Miocene) sequence exposed east of the fault and an Upper Tertiary (middle Miocene and younger) sequence west of the fault. Both sections have been intruded by numerous diabase bodies. Pleistocene marine terrace deposits and minor stream terrace gravels cap much of the western part. Alluvium covers the Tustin Plain and underlies the lowland surface north of the hills.

Bedrock Units

The eastern, older sequence of rocks is divided into the Silverado Formation of Paleocene age, the Santiago Formation of Eocene age, the Sespe Formation of late Eocene(?) to early Miocene age, and the Vaqueros Formation of early Miocene age. All but the Vaqueros Formation and a thin horizon in the Silverado Formation are predominantly nonmarine.

The nonmarine strata consist of poorly sorted, generally massive or crossbedded, arkosic sandstone interbedded with silty sandstones, siltstones, and minor claystones. A very light gray sandy clay bed, similar to the Serrano clay bed in the Santa Ana Mountains, occurs in the upper part of the Silverado Formation. The Sespe Formation and, to a lesser extent, the Santiago Formation have red and green claystone beds, which, in the Sespe Formation, may be as much as 100 feet thick. A persistent series of these colorful claystones occurs in the Sespe Formation immediately below the contact with the overlying marine Vaqueros Formation. Interfingering of the Sespe and Vaqueros Formations may occur north of Sand Canyon Reservoir where cross-bedded sandstones containing varicolored volcanic clasts are interbedded with fossiliferous, massive siltstones.

The Vaqueros Formation, characterized by brown massive sandy siltstone and gray resistant coquina beds, is finer grained and more massive than the underlying nonmarine rocks.

Cross-bedded sandstone beds typical of the underlying nonmarine rocks are not present in the Vaqueros Formation.

Younger rocks, exposed west of the Shady Canyon fault, include the Topanga Formation of middle Miocene age, the Monterey Formation of middle to upper Miocene age consisting chiefly of marine thin-bedded siltstones and siliceous shale, and the Niguel Formation of Pliocene age composed of massive fine-grained sandstones. The Niguel Formation was mapped as an unnamed sandstone unit by Vedder *et al.* (1957). The name Niguel Formation is used in this study to be consistent with the formational names used in the Capistrano embayment to the southeast.

The Topanga Formation is divided into the Bommer, Los Trancos, and Paularino Members in order of decreasing age. The Bommer Member is characterized by resistant thick-bedded coarse-grained sandstones. The overlying Los Trancos Member consists of less resistant thin-bedded siltstone, shale, and fine-grained sandstone. The Paularino Member is comprised of tuffaceous siltstones and sandstones locally interbedded and intertongued with resistant andesitic sedimentary breccia, andesite flows, and flow breccia.

Surficial Deposits

A large percentage of the area is capped by Pleistocene marine terrace deposits and late Pleistocene river terraces. Holocene alluvium covers the Tustin Plain north of the San Joaquin Hills and the stream channels of a few main drainages. The other surficial materials mapped are slopewash, landslide deposits, pond deposits, and man-made fill.

Structure

The dominant structure in the area is faulting, most of which is subparallel to the major northwest-trending Shady Canyon fault. Some folding occurs in the western part of the map area in the Los Trancos and Paularino Members of the Topanga Formation. The eastern part of the area is defined by a combination of fault blocks, each with homoclinal structure, that form over-all anticlinal-synclinal patterns, essentially without folding. This is seen best in the "axis" area of the anticlinal structure immediately east of Sand Canyon in the Santiago Formation, where the strike changes nearly 180° across the faults.

The Shady Canyon fault, bisecting the study area in a northwesterly direction, has a stratigraphic separation of about 5,000 feet and is pre-late middle Miocene in age (Vedder, 1970, p. 19; Morton *et al.,* 1974). The Shady Canyon fault clearly separates the area into an upthrown block exposing early Miocene and older rocks on the east and a downthrown block exposing rocks of middle Miocene and younger age to the west. The northwestern subsurface extension of the fault has been located by oil exploration borings in the Tustin Plain. Where the Shady Canyon fault is mapped as concealed by marine terrace deposits, there are suggestions of a lineament in the topographic expression of the marine terrace (a recent drainage on the terrace and a terrace edge).

The Pelican Hill fault, a probable branch of the Newport-Inglewood fault system, extends into the southwest part of the map area for only a short distance where it apparently is covered by marine terrace deposits. The fault was not observed during this study due to various man-made developments. Less than a mile south of the area, a branch of the Pelican Hill fault has displaced the higher marine terrace deposits, indicating late Pleistocene or younger activity (Tan and Edgington, 1976); however, evidence for such late movement was not found in the study area. According to Vedder (1970, p. 18-19), recurrent vertical and lateral movement on the Pelican Hill fault took place in Miocene and Pliocene time. Another fault displacing marine terrace deposits traverses northwesterly across the University of California, Irvine campus.

GEO-ENVIRONMENTAL PROBLEMS

Slope Stability

In the south half of the Tustin 7.5-minute quadrangle, the propensity of a slope for failure is dependent on several, often interrelated, factors. The most important of these are the lithology of underlying rocks, the angle and structure of the rocks (bedding, jointing, faulting), and the ability of the material to retain moisture. The units most prone to slope failure are the Los Trancos Member of the Topanga Formation, the Vaqueros Formation, and sections of the upper Sespe Formation. These least stable units tend to be softer and finer grained than the more stable units. The structures most important to slope failure in this area appear to be bedding and faulting. Dip slopes often show signs of failure even in the more stable units. A few landslides appear to be associated with faults and probably are related to the weakening effect of the fault zone on the adjacent rock. Most failures occur on north- and east-facing slopes where there is less sunlight and consequently a lower evaporation rate; greater moisture in bedrock on these slopes accounts, in part, for the greater number of failures.

Bedrock landsliding, the most common form of slope failure in the study area, occurs in the Los Trancos Member of the Topanga Formation along the southwest boundary of the area and in the Vaqueros and Sespe Formations in the eastern part of the area. Most of the slides are only a few acres in surface area, although the largest covers more than 30 acres near the eastern boundary of the quadrangle.

Surficial slumps and skin-failures are found on some of the steeper slopes in the Los Trancos Member and to a lesser degree in the Vaqueros Formation. Although some surficial failures cover as much as 3 acres, they are not as hazardous in the study area as are the more voluminous bedrock landslides. Surface failures usually involve only the soil or colluvial layer overlying bedrock. Rockfall occurs infrequently on the steepest slopes, where resistant sandstone or unweathered diabase is exposed.

Seismicity

Since 1934, three earthquake epicenters have been recorded instrumentally in the study area, all with magnitudes less than 4.0 (Hileman *et al.*, 1973); however, this area is seismically active, and large ground motion can be expected to occur as the result of a large-magnitude earthquake generated in southern California. The faults most likely to generate earthquakes in the mapped area are the San Andreas (43 miles), the San Jacinto (37 miles), the Elsinore-Whittier (12 miles), and the Newport-Inglewood (2.5 miles.) The Norwalk fault, 5 miles north of the mapped area, also has been suggested to be active (Richter, 1958). Ground shaking in the study area would be greatest in the more unconsolidated Quaternary deposits, especially where the ground-water level is nearest the surface, such as the marsh area in upper Newport Bay (Barosh, 1969). The least response would occur in the more resistant bedrock; however, landsliding may be triggered in the bedrock underlain by the units most susceptible to slope failure.

Table 1. Historic earthquakes potentially damaging to structures in the S½ Tustin 7½′ quadrangle *(Morton et al., 1974).*

DATE	APPROXIMATE AREA OF ORIGIN	MODIFIED MERCALLI INTENSITY NEAR ORIGIN	MAGNITUDE
1769 July 28	Not known but noted by Portola expedition near mouth of Santa Ana Canyon	?	?
1812 Dec 8	Not known but severely damaged Missions San Juan Capistrano and Santa Ynez	IX-X	7*
1857 Jan 9	Fort Tejon region	X-XI	8.0*
1892 Feb	Baja California, Mexico	?	7.0*
1893 April 4	Newhall	VIII-IX	?
1899 Dec 25	San Jacinto-Hemet	IX	7.0*
1918 April 21	San Jacinto-Hemet	IX	7.0*
1923	San Bernardino	?	6.0*
1933 March 10	Long Beach (offshore)	IX	6.3*
1938 May 31	Santa Ana Mountains (Upper Trabuco Canyon)	VI	5.5
1956 Jan 3	Riverside County (Glen Ivy)	VI	4.7

*Estimated

One fault in the area mapped has shown possible evidence of movement during Quaternary time. The fault, which crosses the University of California at Irvine campus, was examined by Geolabs-California, Inc., (1968) during the initial geologic investigation of the University site. This fault displaced a section of older marine terrace deposits, but it reportedly did not disturb the most recent marine terrace in that section and is considered to have been inactive since the beginning of the Holocene. Landscaping of the campus subsequent to that investigation prevented a study of this fault during the investigation for this report.

The Pelican Hill fault zone, trending northwest, extends into the area in the southwest corner. One mile south, along this fault zone, a branch fault has displaced the higher marine terrace deposits in the vicinity of Spy Glass Hill, indicating at least late Pleistocene activity. However, no indications of Pleistocene or Holocene movement were found along this fault zone within the Tustin quadrangle.

Mineral Resources

The only mineral resources in the study area are clay, low-quality aggregate, and foundry sand.

The conglomeratic sandstone horizons of the Sespe Formation exposed immediately east of Sand Canyon Dam and perhaps those exposed along the southeastern boundary of the quadrangle may have some value in the future. At present, these deposits are of no economic importance due to their excessive fines and minor gravel-size fraction.

The clay horizon exposed for about 1 mile in the Silverado Formation may be a source of ceramic clay. It has been mapped as a separate dashed-line symbol as noted on the geologic map. In most places, it is more than 20 feet thick and composed of very light gray sandy claystone. It is overlain by a resistant sandstone layer and commonly dips about 15° to the west. The exposures of this clay bed are discontinuous to the north due to displacements along faults. Laboratory analyses of samples taken from this clay bed show a kaolinite content ranging from 6.3 to 17.9%, well below the percentage of nearby commercial clay beds in the Santa Ana Mountains.

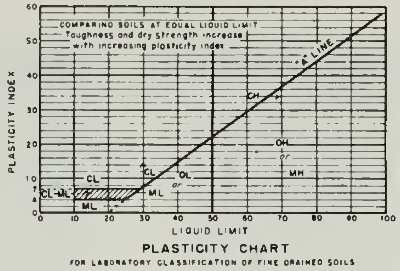
Foundry sand was mined from the marine terrace deposits along Jamboree Road prior to the development of that area.

Table 2. Unified soil classification chart.

UNIFIED SOIL CLASSIFICATION

INCLUDING IDENTIFICATION AND DESCRIPTION

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 3 inches and basing fractions on estimated weights)				GROUP SYMBOLS ∟	TYPICAL NAMES	INFORMATION REQUIRED FOR DESCRIBING SOILS	LABORATORY CLASSIFICATION CRITERIA			
COARSE GRAINED SOILS More than half of material is larger than No 200 sieve size ■ (The No 200 sieve size is about the smallest particle visible to the naked eye)	GRAVELS More than half of coarse fraction is larger than No 4 sieve size (For visual classifications, the 1/4" size may be used as equivalent to the No 4 sieve size)	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes	GW	Well graded gravels, gravel-sand mixtures, little or no fines	Give typical name, indicate approximate percentages of sand and gravel, max size, angularity, surface condition, and hardness of the coarse grains, local or geologic name and other pertinent descriptive information, and symbol in parentheses For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions and drainage characteristics EXAMPLE.- Silty sand, gravelly, about 20% hard, angular gravel particles $\frac{1}{2}$-in maximum size; rounded and subangular sand grains coarse to fine, about 15% non-plastic fines with low dry strength, well compacted and moist in place, alluvial sand, (SM)	Use grain size curve in identifying the fractions as given under field identification	Determine percentages of gravel and sand from grain size curve Depending on percentage of fines (fraction smaller than No 200 sieve size) coarse grained soils are classified as follows - Less than 5 % GW, GP, SW, SP. More than 12 % GM, GC, SM, SC. 5 % to 12 % Borderline cases requiring use of dual symbols	$C_u = \frac{D_{60}}{D_{10}}$ Greater than 4 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between one and 3	
			Predominantly one size or a range of sizes with some intermediate sizes missing	GP	Poorly graded gravels, gravel-sand mixtures, little or no fines				Not meeting all gradation requirements for GW	
		GRAVELS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)	GM	Silty gravels, poorly graded gravel-sand-silt mixtures				Atterberg limits below "A" line, or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols
			Plastic fines (for identification procedures see CL below)	GC	Clayey gravels; poorly graded gravel-sand-clay mixtures				Atterberg limits above "A" line with PI greater than 7	
	SANDS More than half of coarse fraction is smaller than No 4 sieve size	CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes	SW	Well graded sands, gravelly sands, little or no fines				$C_u = \frac{D_{60}}{D_{10}}$ Greater than 6 $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between one and 3	
			Predominantly one size or a range of sizes with some intermediate sizes missing	SP	Poorly graded sands, gravelly sands, little or no fines				Not meeting all gradation requirements for SW	
		SANDS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)	SM	Silty sands, poorly graded sand-silt mixtures				Atterberg limits below "A" line or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols
			Plastic fines (for identification procedures see CL below)	SC	Clayey sands, poorly graded sand-clay mixtures				Atterberg limits above "A" line with PI greater than 7	

	IDENTIFICATION PROCEDURES ON FRACTION SMALLER THAN No. 40 SIEVE SIZE						
		DRY STRENGTH (CRUSHING CHARACTERISTICS)	DILATANCY (REACTION TO SHAKING)	TOUGHNESS (CONSISTENCY NEAR PLASTIC LIMIT)			
FINE GRAINED SOILS More than half of material is smaller than No 200 sieve size (The No 200 sieve size is about the smallest particle visible to the naked eye)	SILTS AND CLAYS Liquid limit less than 50	None to slight	Quick to slow	None	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity	Give typical name, indicate degree and character of plasticity, amount and maximum size of coarse grains, color in wet condition, odor if any, local or geologic name, and other pertinent descriptive information, and symbol in parentheses For undisturbed soils add information on structure, stratification, consistency in undisturbed and remolded states, moisture and drainage conditions EXAMPLE.- Clayey silt, brown, slightly plastic, small percentage of fine sand, numerous vertical root holes, firm and dry in place, loess, (ML)	 PLASTICITY CHART FOR LABORATORY CLASSIFICATION OF FINE GRAINED SOILS
		Medium to high	None to very slow	Medium	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays		
		Slight to medium	Slow	Slight	OL	Organic silts and organic silt-clays of low plasticity		
	SILTS AND CLAYS Liquid limit greater than 50	Slight to medium	Slow to none	Slight to medium	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts		
		High to very high	None	High	CH	Inorganic clays of high plasticity, fat clays		
		Medium to high	None to very slow	Slight to medium	OH	Organic clays of medium to high plasticity		
HIGHLY ORGANIC SOILS		Readily identified by color, odor, spongy feel and frequently by fibrous texture			Pt	Peat and other highly organic soils		

∟ Boundary classifications - Soils possessing characteristics of two groups are designated by combinations of group symbols For example GW-GC, well graded gravel-sand mixture with clay binder

■ All sieve sizes on this chart are US standard

FIELD IDENTIFICATION PROCEDURES FOR FINE GRAINED SOILS OR FRACTIONS

These procedures are to be performed on the minus No 40 sieve size particles, approximately $\frac{1}{64}$ in For field classification purposes, screening is not intended, simply remove by hand the coarse particles that interfere with the tests

DILATANCY (Reaction to shaking)

After removing particles larger than No 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch Add enough water if necessary to make the soil soft but not sticky

Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens, and finally it cracks or crumbles The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.

Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction Inorganic silts, such as a typical rock flour, show a moderately quick reaction

DRY STRENGTH (Crushing characteristics)

After removing particles larger than No 40 sieve size, mold a pat of soil to the consistency of putty, adding water if necessary Allow the pat to dry completely by oven, sun, or air drying, and then test its strength by breaking and crumbling between the fingers This strength is a measure of the character and quantity of the colloidal fraction contained in the soil The dry strength increases with increasing plasticity

High dry strength is characteristic for clays of the CH group A typical inorganic silt possesses only very slight dry strength Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen Fine sand feels gritty whereas a typical silt has the smooth feel of flour

TOUGHNESS (Consistency near plastic limit)

After removing particles larger than the No 40 sieve size, a specimen of soil about one-half inch cube in size is molded to the consistency of putty If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about one-eighth inch in diameter The thread is then folded and rerolled repeatedly During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached

After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles

The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line

Highly organic clays have a very weak and spongy feel at the plastic limit

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KEY TO MAP UNIT CHARACTERISTICS

TERRAIN FEATURES

Topographic expression: Each geologic unit erodes in a characteristic way resulting in a certain overall topographic expression.
Vegetation: Type of vegetation naturally occurring on the map unit.
Approximate natural slope angles: Average normal range of slope angles. Deviations from this norm do occur.
Slopewash development: Degree to which eroded debris from the unit tends to accumulate and its nature.
Topsoil development: Type and extent characteristic to the map unit.

LITHOLOGIC FEATURES

Type and color: Predominant rock types listed in order of abundance. Color designations are according to the Munsell System Rock Color Chart (see Goddard *et al.*, 1951).
Bedding: Relative degree and character of development of layered arrangement of sediments resulting from original depositional mode of accumulation.
Induration: Relative degree of hardness or consolidation and character of cementation if present.
Angularity: Approximation of the average degree of angularity or roundness of grains and clasts in the unit.
Sorting: Relative degree of similarity in size of individual grains occurring in the sedimentary unit.
Composition: General composition. No exhaustive analyses were attempted.
Structure: Arrangement or configuration of bedding, jointing, fracturing, or other planar features of the unit.
Thickness: Maximum dimension of accumulation of the unit measured normal to the bedding or, in the case of intrusives, measured normal to the primary boundaries.
Contact relations: Nature of the interface between contiguous map units.
Age and fossils: Geologic age and significant fossil occurrences.
Distribution and correlation: Areal distribution in the map area and other units which are age equivalents elsewhere in Orange County.

ENGINEERING FEATURES

Unified soil classification: Size classification of grain size occurring in a sedimentary unit if the material is in a disaggregated state (as adopted by the U.S. Corps of Engineers and U.S. Bureau of Reclamation).
Natural dry density: Range of natural dry densities of major rock types in the unit given in pounds per cubic foot (pcf).
Permeability: Empirical designation of relative ease of water movement through the rock unit.
Porosity: Empirical designation of relative degree of water absorption capability.
Ease of excavation: Ease of excavation by commonly used contemporary equipment.
Slope stability: Propensity of the rock unit to slope failure of various types.
Fabric: Relative degree of structural grain imparted to the unit as a whole by arrangement of linear or planar elements such as beds, joints, fractures, lineation of mineral grains, etc.
Expansivity: Designation of relative degree of expansion when wetted
Erodibility: Relative degree of susceptibility to erosion.

USE POTENTIAL

Mineral deposits: Known or possible mineral resource potential of unit.
Fill materials: Amenability for use as fill materials of various types.
Waste disposal sites: General evaluation of the gross aspects of the formation relative to siting of Class II and Class III disposal sites (as adopted by the California State Water Resources Control Board, 1972).
Ground-water aquifer: Evaluation of potential as a reservoir rock for ground water.

NOTES: The use of "moderately low", "moderately high", "high", etc., in this table is an attempt to qualify empirical information for which adequate test data are not available.

Pond deposits (Qp) and artificial fill (af) are not included in this table; pond deposits because of their inaccessibility for observation and artificial fill because of its inhomogeneity.

MAP UNIT CHARACTERISTICS

ALLUVIUM (Qal)—canyon and valley bottom areas

TERRAIN FEATURES

Topographic expression: Occupies low areas in canyons and valleys, commonly incised by gullies cut by intermittent runoff.
Vegetation: Very little natural vegetation exists due to extensive plowing. Existing natural vegetation consists of woodlands of sycamore, oak, and alder.
Approximate natural slope angles: Generally less than 10° except along gully walls where 70° slopes exist.
Slopewash development: Absent.
Topsoil development: Generally moderate to thick with thinner soils found on clean sand or gravelly materials. Sand and clay loams most common.

LITHOLOGIC FEATURES

Type and color: Color widely variable depending on source area. Predominantly silt and gravel with large amounts of peat in the San Diego Creek valley northeast of upper Newport Bay.
Bedding: Lenticular and crossbedded.
Induration: Unconsolidated to moderately well consolidated. Generally uncemented.
Angularity: Subangular to angular sand grains; subangular to rounded clasts. Angularity of clasts dependent on source material; reworked sedimentary beds contribute large percentages of the more rounded clasts.
Sorting: Poorly sorted.
Composition: Varied; dependent on source area. Quartzo-feldspathic sands with peninsular range clasts predominating significant amounts of "Poway" clasts in alluvium derived from the Sespe Formation.
Structure: Flat lying to gently dipping in crossbeds.
Thickness: As much as 90 feet in the major drainages; may be thicker in the San Diego Creek Valley above Newport Bay.
Contact relations: Unconformably overlies bedrock units. Interfingers with Tustin Plain alluvium and slopewash along sides of canyons.
Age: Holocene.
Distribution: The bottom areas of the main drainages including that part of the course of San Diego Creek which has incised the marine terrace from half a mile southwest of Lane Road to upper Newport Bay.

ENGINEERING FEATURES

Unified soil classification: GW, GP, GM, ML, MH, SM, and SW.
Natural dry density: Extremely variable.
Permeability: Variable but mostly high.
Porosity: Highly variable.
Ease of excavation: Generally easily excavated.
Slope stability: Banks of gullies and stream channels commonly slough.
Fabric: Poorly developed; fails massively.
Expansivity: Highly variable but mostly low.
Erodibility: Moderately high to high on gully and stream channel banks and excavated slopes.

USE POTENTIAL

Mineral deposits: None. Sand and gravel potential is low due to small gravel fraction.
Fill materials: Alluvial material well suited for pervious fill.
Waste disposal sites: Unsuitable for Class II disposal sites due to high permeability and ground water content. May be suitable for Class III disposal sites where there is low erosion potential.
Ground-water aquifer: Excellent. Several wells are producing water from canyon and valley alluvium.

ALLUVIUM (Qal)—Tustin Plain

TERRAIN FEATURES

Topographic expression: Gently sloping to flat plain incised by vertical sided gullies.
Vegetation: The Tustin Plain has been extensively cultivated and supports little or no natural vegetation.
Approximate natural slope angles: 0° to 3°, excepting channel cut banks.
Slopewash development: Absent.
Topsoil development: The alluvial plain in the northeast corner of the area has developed a thick clay loam soil; the remaining plain area supports a soil layer rarely thicker than 3 to 4 feet.

LITHOLOGIC FEATURES

Type and color: The uppermost 50 feet of alluvium generally consists of sandy clay, black and red clay, and sand with minor amounts of gravel.
Bedding: Locally crudely stratified or crossbedded.
Induration: Absent or poorly indurated; poorly consolidated.
Angularity: Subangular to subrounded.
Sorting: Poorly sorted.
Composition: Variable. Mostly quartzo-feldspathic sand with basement rock clasts from the Santa Ana Mountains.
Structure: Gently dipping toward the northwest.
Thickness: Bedrock is covered by from 90 feet to 200 feet of alluvium—thinnest along the southern margin of the plain and thickening to the north. There is less of a thickening from east to west along the north margin of the area.
Contact relations: Unconformably overlies bedrock formations and interfingers with stream alluvium issuing from the canyons in the San Joaquin Hills.
Age: Uppermost 50 feet is Holocene.
Distribution: The area includes the plain north of the northernmost exposures of bedrock and marine terrace.

ENGINEERING FEATURES

Unified soil classification: Variable; mostly SM, SP, SW, SC, CL, CH, OH, and minor gravel, GW, GP, GM.
Natural dry density: Sand ranges from 86 to 122 pcf and clays from 77 to 123 pcf.
Permeability: High to moderately high in sand and gravels. Lower in clayey material.
Porosity: Moderately low to high.
Ease of excavation: Generally easily excavated.
Slope stability: Gully sides commonly slough.
Fabric: Poorly developed; reacts massively.
Expansivity: Generally low but clays are highly expansive. Soils are generally highly expansive.
Erodibility: Highly erodible in exposed slopes.

USE POTENTIAL

Mineral deposits: None.
Fill materials: Generally suitable for slightly pervious or pervious fill.
Waste disposal sites: Not suitable for Class II waste disposal sites due to probable contamination of ground water. Suitable for Class III disposal sites.
Ground-water aquifer: Excellent; a number of producing water wells have been drilled in this area of the Tustin Plain.

SLOPEWASH (Qsw)

TERRAIN FEATURES

Topographic expression: Forms aprons at the bases of slopes and fills small re-entrant gullies; subdues change of slope angle between bedrock and gently inclined water courses.
Vegetation: Variable due to wide distribution and differing source material.
Approximate natural slope angles: 0° to 10°.
Slopewash development: —
Topsoil development: —

LITHOLOGIC FEATURES

Type and color: Variable. Reflects soil development of bedrock source.
Bedding: Generally absent. Some stratification may be present.
Induration: Unconsolidated.
Angularity: Variable. Reflects bedrock source.
Sorting: Generally unsorted.
Composition: Mainly derived from soils developed on adjacent bedrock. Variable amounts of organic debris may be present.
Structure: Absent.
Thickness: Mapped areas represent slopewash thought to be at least 3 feet thick. Some accumulations may be as much as 15 feet thick.
Contact relations: Unconformably overlies bedrock and interfingers with alluvium along drainage courses.
Age: Holocene.
Distribution: Found along most of the drainage courses in the area as well as isolated patches in the upper reaches of some. Broad areas underlain by slopewash border the Tustin Plain in the eastern portion of the quadrangle.

ENGINEERING FEATURES

Unified soil classification: Variable. Reflects bedrock source.
Natural dry density: Highly variable; mostly low.
Permeability: Moderate to high depending on bedrock source.
Porosity: Variable. Reflects bedrock source.
Ease of excavation: Easily graded.
Slope stability: Poor. May slump along cut banks in drainages, or move swiftly down a steep drainage as a mudflow when saturated.
Fabric: Absent.
Expansivity: Variable. Tends to be higher than bedrock source (see individual unit descriptions).
Erodibility: High on moderate or steeper slopes.

USE POTENTIAL

Mineral deposits: None.
Fill materials: Most is unsuitable due to high soil content. Some derived from sandstone with low clay content may be suitable.
Waste disposal sites: Not suitable for Class II or Class III due to erodibility and permeability.
Ground-water aquifer: Low due to limited extent.

LANDSLIDE (Qls)

TERRAIN FEATURES

Topographic expression: Larger landslides form hummocky, subdued terrain commonly with a flat upper surface bordered by an abrupt rise of an arcuate-shaped up-slope boundary; lower boundary commonly marked by a crowded or diverted drainage course. Smaller landslides often form single lumps sitting below a steepened slope.
Vegetation: Commonly grassier than adjacent slopes.
Approximate natural slope angles: Variable, but often less than adjacent slopes.
Slopewash development: Variable, but occasionally yields great amounts, choking drainage channels below older slides. Development is generally more rapid than that of parent bedrock.
Topsoil development: Variable. Development is generally more rapid than that of parent bedrock due to less consolidated state of landslide material.

LITHOLOGIC FEATURES

Type and colors: Variable; dependent on bedrock source.
Bedding: Absent or chaotic in most landslides. Same as bedrock source in possible block-glide landslides.
Induration: Very poor to moderately poor in most landslide materials. Block-glide landslides will retain induration of parent bedrock.
Angularity: Dependent on bedrock source but tends to be angular to blockly.
Sorting: Unsorted.
Composition: Dependent on bedrock source.
Structure: Generally chaotic except in possible block-glide landslides.
Thickness: Generally less than a hundred feet.
Contact relations: Unconformably overlies bedrock units.
Age: Holocene and Pleistocene. The largest slides are probably among the oldest.
Distribution: Occur on most bedrock units; more numerous in areas underlain by the Los Trancos Member of the Topanga Formation and the Vaqueros Formation.

ENGINEERING FEATURES

Unified soil classification: Variable; dependent on bedrock source.
Natural dry density: Variable.
Permeability: Generally moderately high to high.
Porosity: Generally moderately high to high.
Ease of excavation: Generally easy; moderately easy in possible block-glide landslides.
Slope stability: Poor. Renewed movement of all or portions of a landslide is common.
Fabric: Generally absent. Possible block-glide landslides retain the fabric of the parent bedrock.
Expansivity: Variable; dependent on bedrock source.
Erodibility: Much more susceptible than parent bedrock.

USE POTENTIAL

Mineral deposits: None.
Fill materials: Variable; dependent on bedrock source.
Waste disposal sites: Unsuitable for waste disposal sites.
Ground-water aquifer: Most landslides contain ground water, but amounts are limited according to the size of the landslide. At least one has a spring near its base.

RIVER TERRACE (Qtr)

TERRAIN FEATURES

Topographic expression: Bench-like platform areas flanking major drainages.
Vegetation: Grass covered with some low brush.
Approximate natural slope angles: 1° to 20°.
Slopewash development: Contributes moderate amounts of slopewash.
Topsoil development: Thicker terraces support fairly well developed clay loam.

LITHOLOGIC FEATURES

Type and color: Yellowish-brown silty to clayey gravel and clayey silt and sand lenses.
Bedding: Crudely bedded and crossbedded.
Induration: Moderately well to poorly consolidated; poorly cemented.
Angularity: Variable.
Sorting: Very poor except for local well-sorted lenses.
Composition: Variable; dependent on source area.
Structure: Flat to very gently dipping.
Thickness: Generally less than 30 feet.
Contact relations: Unconformably overlies bedrock.
Age: Pleistocene.
Distribution: Scattered along a few major drainages.

ENGINEERING FEATURES

Unified soil classification: GM, GC, SM, and SC.
Natural dry density: No data.
Permeability: Moderately high to moderately low.
Porosity: Moderate.
Ease of excavation: Easy to moderately easy.
Slope stability: Generally stable.
Fabric: Minimal to absent. Reacts massively.
Expansivity: Low to moderate. Residual soils high.
Erodibility: Moderately low.

USE POTENTIAL

Mineral deposits: None. Sand and gravel potential low due to limited extent of terraces with adequate gravel content.
Fill materials: Variable. Impervious fill available from westernmost terraces; more pervious fill available from easterly terraces.
Waste disposal sites: Unsuitable for Class II sites due to permeability and thinness of terraces. Larger terraces may be suitable for Class III sites.
Ground-water aquifer: Low, due to limited volume of unit.

MARINE TERRACE (Qtm)

TERRAIN FEATURES

Topographic expression: Gently undulating surface, in places cut by steep-sided ravines.
Vegetation: Grasses and scattered shrubs. Local, moderate brush cover.
Approximate natural slope angles: Mostly gently inclined broad surfaces incised by steep-walled ravines having slopes up to 33°.
Slopewash development: Poor.
Topsoil development: Up to 20 inches of pale brown sandy to clayey loam.

LITHOLOGIC FEATURES

Type and color: Light brown to yellowish-brown fine sand and silty sand and gray coarse-grained sand and gravel and some silt.
Bedding: Poorly bedded. Lenticular and crossbedded.
Induration: Poorly to moderately consolidated. Locally weakly cemented.
Angularity: Subrounded to rounded.
Sorting: Moderately well sorted.
Composition: Sand grains mostly quartz and feldspar with some lithic grains. Clasts varied.
Structure: Flat lying to very gently dipping. Deposited on wave-cut platforms that now lie at elevations of 50 to 200 feet.
Thickness: Maximum of about 125 feet near the western edge of the quadrangle. Generally thinner toward the hills (southeast).
Contact relations: Unconformably overlies Pliocene and Miocene Formations (Niguel, Monterey, and Paularino and Los Trancos Members of the Topanga).
Age and fossils: Late Pleistocene. Abundant mollusks can be found in many of the terraces near the southwestern corner of the quadrangle. All are Panamanian in age; included are *Trachycardium procerum, Petricola parallela,* and *"Nassa" cerritensis* (Valentine, 1961, p. 367).
Distribution and correlation: Extensive areas covered by marine terrace deposits in the western portion of the area. Correlated with the La Habra Formation in northern Orange County.

ENGINEERING FEATURES

Unified soil classification: Common SP and SM, minor GP.
Natural dry density: 80 to 100 pcf.
Permeability: Moderate to high.
Porosity: Moderate to high.
Ease of excavation: Generally easily excavated.
Slope stability: Good to fair. Local cementation may support steep slopes.
Fabric: Poorly developed.
Expansivity: Nonexpansive to moderately expansive. Topsoil is generally highly expansive.
Erodibility: Moderately low in natural and excavated slopes; except in uncemented material which easily runs.

USE POTENTIAL

Mineral deposits: Foundry sand was mined from the terrace now developed by housing along Jamboree Road.
Fill materials: Well suited for pervious fill. Several borrow pits have been excavated for this purpose.
Waste disposal sites: Poorly suited for Class II sites due to high permeability and, in eastern terraces, thinness. Well suited for Class III sites.
Ground-water aquifer: Poor, due to elevated position.

NIGUEL FORMATION (Tn)

TERRAIN FEATURES

Topographic expression: Exposed only in steep banks along upper Newport Bay and Bonita Canyon and in McArthur Boulevard and other road cuts.
Vegetation: Little or no natural vegetation.
Approximate natural slope angles: 10° to 60°.
Slopewash development: Moderately thick accumulations of silty and sandy slopewash.
Topsoil development: Little or no residual soil development.

LITHOLOGIC FEATURES

Type and color: Marine; light brown to yellowish-brown siltstone and fine-grained sandy siltstone, commonly with calcareous nodules.
Bedding: Poorly developed. Massive to thick bedded.
Induration: Moderately well consolidated; poorly cemented.
Angularity: Subangular to angular sand-size grains.
Sorting: Well sorted.
Composition: Quartzo-feldspathic sandy siltstone.
Structure: Moderately dipping to the north.
Thickness: Exposed section is about 1,050 feet thick (Vedder, 1970).
Contact relations: Unconformably overlies the Monterey Formation and the Paularino Member of the Puente Formation. It is unconformably overlain by marine terrace material.
Age and fossils: Early Pliocene to Early Pleistocene. Abundant foraminifera including *Globoquadrina dutertrei, Globigerina pachyderma,* and *Globorotalia truncatulinoides.*
Distribution and correlation: Exposed in the cliffs bordering upper Newport Bay, along lower Bonita Canyon and in several nearby roadcuts. Correlates with Fernando Formation in northern Orange County.

ENGINEERING FEATURES

Unified soil classification: SM, ML, and MH.
Natural dry density: 100 to 110 pcf is the normal range elsewhere in Orange County.
Permeability: Moderately high.
Porosity: Moderately high to moderately low.
Ease of excavation: Easy.
Slope stability: Moderately high.
Fabric: Nearly absent.
Expansivity: Low.
Erodibility: Moderately high to moderately low.

USE POTENTIAL

Mineral deposits: None.
Fill materials: Suitable for pervious and semi-pervious fills.
Waste disposal sites: Not suited due to limited exposure and proximity to urban development.
Ground-water aquifer: Good. It has moderately high porosity and permeability and it underlies much of the Tustin Plain.

MONTEREY FORMATION (Tm)

TERRAIN FEATURES

Topographic expression: Exposed in the area only in steep banks along large canyons.
Vegetation: Little or no natural vegetation.
Approximate natural slope angles: 7° to 25°.
Slopewash development: Thick accumulations in canyon bottoms reaching 10 to 20 feet. Usually contains highly plastic clay and siliceous shale boulders.
Topsoil development: Little or no residual soil developed on the Monterey Formation in the area.

LITHOLOGIC FEATURES

Type and color: White to yellowish-gray siliceous shale, cherty shale and siltstone with minor limy sandstone lenses.
Bedding: Very well developed. Thinly bedded to very thinly bedded.
Induration: Generally moderately well indurated; siliceously cemented or limy beds may be very hard. Shale and siltstone become soft when saturated with water.
Angularity: Sandstone interbeds have subangular sand-size grains.
Sorting: Sandstones are poorly sorted.
Composition: Siltstone and shale are diatomaceous and tuffaceous; montmorillonite clay is common.
Structure: Moderately dipping to the north.
Thickness: Only a few hundred feet exposed in the area.
Contact relations: Unconformably overlies the Paularino Member of the Topanga Formation and is unconformably overlain by the Niguel Formation.
Age and fossils: Late Miocene. Abundant Foraminifera.
Distribution and correlation: Exposed in the southwest corner of the area and along Bonita Canyon Road. Correlates with part of the Puente Formation in northern Orange County.

ENGINEERING FEATURES

Unified soil classification: SM and ML to CL and CH.
Natural dry density: Siltstone ranges from 36 to 88 pcf depending on diatomaceous material content. Sandstone is estimated at 90 pcf from one sample outside of the area.
Permeability: Generally very low; joints may provide avenues for water flow.
Porosity: Very high.
Ease of excavation: Moderately easy.
Slope stability: Poor. Many landslides have involved this unit outside of the area.
Fabric: Well developed. Generally fissile bedding combined with defined jointing.
Expansivity: High.
Erodibility: Moderately low to moderately high in natural slopes. Moderately low in excavated slopes.

USE POTENTIAL

Mineral deposits: None.
Fill materials: Poor to fair for impervious fill. Low compactibility, high expansivity, and low density.
Waste disposal sites: Nearly all of the area underlain by the Monterey Formation in the area has been developed; otherwise it would be suitable for Class II and III sites.
Ground-water aquifer: Poor. Very low permeability.

PAULARINO MEMBER—TOPANGA FORMATION (Ttp)

TERRAIN FEATURES

Topographic expression: Forms moderate to steep sloped valleys and mesas and rounded hill tops with gentle to steep slopes. The breccias and flows generally form rugged topography with steep and rocky slopes and hills.

Vegetation: Generally grassland and mustard, with high brush and chaparral mainly in areas underlain by flow and breccia.

Approximate natural slope angles: Average: 10° to 30°. Some parts of incised slopes and hillsides may exceed 60°, particularly in areas underlain by resistant sandstones, breccias, and flows.

Slopewash development: Generally absent to thin, but thick along major drainage. Absent on resistant rocks (breccias, flows and some resistant sandstones) and thin on weak siltstones and shales.

Topsoil development: Absent to moderately thick. Absent on resistant rocks (breccias, flows, and some resistant sandstone), thin to moderately thick on less resistant shales, siltstones and sandstones.

LITHOLOGIC FEATURES

Type and color: Marine sandstone, siltstone, and shale, and possibly nonmarine breccia and flows. Light gray, yellowish-gray and light olive-gray, tuffaceous siltstone, fine- to coarse-grained sandstone and shale. Dark to medium dark gray, dusky-brown, brownish-black, grayish-brown, brownish-gray sedimentary breccia, andesite flows and flow breccia.

Bedding: Well-bedded shale and siltstone, poorly to moderately bedded sandstone and siltstone, poorly to unbedded breccia and massive flows. Locally folded and contorted thin-bedded shale, siltstone, and sandstone.

Induration: Moderately to well indurated. Some sandstone and most shale and siltstone become soft when saturated. Very hard resistant breccia and flows.

Angularity: Sandstone: subrounded and angular; breccia: angular to subangular.

Sorting: Moderately to poorly sorted sandstone. Poorly sorted breccia.

Composition: Tuffaceous quartzo-feldspathic sedimentary rocks with biotite, montmorillonite clay. Most of breccia clasts and high percentage of sandstone clasts are andesitic; flows are augite-hypersthene andesites.

Structure: Monoclinally dipping to northwest, but locally tightly folded and usually deformed along faults which generally strike northwest and north.

Thickness: 1,500 feet (Vedder, 1970, p. 17).

Contact relations: Unconformably overlain by Monterey Formation and Niguel Formation and conformably underlain by the Los Trancos Member of the Topanga Formation.

Age and fossils: Abundant Foraminifera including *Siphogenerina* cf. *hughesi* and *Valvulineria californica* (Vedder, 1957) indicating middle Miocene.

Distribution and correlation: Exposed west of the Shady Canyon fault on the University of California at Irvine campus and along Bonita Canyon. Correlates with part of the undifferentiated Topanga Formation elsewhere in Orange County. Also, a probable stratigraphic equivalent of the San Onofre Breccia.

ENGINEERING FEATURES

Unified soil classification: Sandstones: SC, SM, siltstones; shales: ML, CL, MH; breccia: GM, GC, some GW.

Natural dry density: Moderate: most sandstone ranges from 120 to 150 pcf, most siltstone ranges from 85 to 100 pcf; breccia and flows range from 150 to 180 pcf.

Permeability: Moderately low due to induration of sediments and moderate silt and clay content.

Porosity: Moderately low.

Ease of excavation: Moderate. Breccia, flow breccia, and flow material is difficult and may require blasting.

Slope stability: Generally good, except for areas underlain by thin-bedded shale, siltstone and less resistant sandstone, where landslides and soil creep are found.

Fabric: Moderately well to poorly developed; massive and thick bedding and moderate joint development, locally thin-bedded shale and siltstone and well bedded sandstone.

Expansivity: Low in general, moderate where underlain by shale and siltstone.

Erodibility: Moderately low to low in both natural and excavated slopes.

USE POTENTIAL

Mineral deposits: None.

Fill materials: Generally well suited for fill. Flows and flow breccia poorly suited due to resistance to excavation.

Waste disposal sites: Fairly well suited for Class II and III disposal sites due to moderately low permeability and moderate ease of excavation (except for the flow and breccia). Ground water barriers may be necessary for Class II sites.

Ground-water aquifer: Poor due to moderately low permeability and porosity.

LOS TRANCOS MEMBER—TOPANGA FORMATION (Ttlt)

TERRAIN FEATURES

Topographic expression: Gentle to steep rounded slopes.
Vegetation: Grass with light to moderate chaparral and brush.
Approximate natural slope angles: 10° to 40°.
Slopewash development: Generally moderately thick.
Topsoil development: Generally moderately thick and expansive, particularly on gentle northerly and easterly facing slopes.

LITHOLOGIC FEATURES

Type and color: Marine; medium to dark gray, yellowish-gray, moderate yellowish-brown, light brownish to light olive-gray siltstone and fine-grained sandstone with interbedded medium to coarse-grained sandstone and shale; locally tuffaceous sandstone.
Bedding: Thin to medium bedded siltstone; locally thick bedded sandstone.
Induration: Moderate; relatively soft siltstone predominant with resistant sandstone interbeds.
Angularity: Mostly subangular to subrounded sandstone grains.
Sorting: Moderately well sorted.
Composition: Quartz, feldspar, lithic grains of quartzite, schist, volcanic and plutonic varieties; sandstones are locally tuffaceous. Limited testing shows that the clay minerals beidellite and montmorillonite are present.
Structure: Moderately steep northwesterly dips. Minor folding north of Bonita Canyon Drive.
Thickness: Maximum thickness of 3,100 feet is estimated in the Coyote Canyon area (Vedder, 1970, p. 8 and 17).
Contact relations: Gradational contact with underlying Bommer Member is seen south of the area. Conformably overlain by the Paularino Member, but local unconformities probably exist.
Age and fossils: Middle Miocene foraminifera; *Valvulineria depressa, Bolivina advena* var., *Baggina cancriformis* (Vedder *et al.,* 1957; Kleinpell, 1938).
Distribution and correlation: Exposed west of the Shady Canyon fault in Turtle Rock Hills and north and south of Bonita Canyon Drive. Correlates with part of undifferentiated Topanga Formation elsewhere in Orange County.

ENGINEERING FEATURES

Unified soil classification: ML-MH, CL-ML, CL, and SC-SM.
Natural dry density: Siltstones range from 98 to 118 pcf; one sample of silty sand was 115 pcf.
Permeability: Low to moderately low.
Porosity: Moderately high to moderately low.
Ease of excavation: Moderate; local cemented strata may be difficult to excavate.
Slope stability: Poor; surficial and bedrock slides are common.
Fabric: Well developed. Thin bedding and shaly strata are common. Moderately developed jointing.
Expansivity: Moderately expansive siltstones.
Erodibility: Moderately low in natural slopes; moderately low to moderately high in excavated slopes.

USE POTENTIAL

Mineral deposits: None.
Fill materials: Fair to poor due to expansivity of silty strata.
Waste disposal sites: Well suited for Class II and III disposal sites due to low to moderately low permeability and moderate ease of excavation.
Ground-water aquifer: Poor due to low to moderately low permeability.

BOMMER MEMBER—TOPANGA FORMATION (Ttb)

TERRAIN FEATURES

Topographic expression: Moderately rounded with resistant outcrops in area.
Vegetation: Grass; barren resistant beds.
Approximate natural slope angles: 5° to 20°.
Slopewash development: Thin to moderate.
Topsoil development: Variable; generally thin sandy to clay loam.

LITHOLOGIC FEATURES

Type and color: Marine; yellowish-gray, dusky yellow, pale yellowish-brown, moderate yellowish-brown, light brownish to light olive-gray medium- to coarse-grained sandstone, locally conglomeratic, and interbedded brownish and olive-gray siltstone and fine-grained sandstone.
Bedding: Thick bedded, commonly broadly lenticular; locally medium to thin bedded.
Induration: Moderately well indurated. Moderately well cemented sandstone predominates with friable sandstone and soft siltstone interbeds.
Angularity: Mostly subangular to rounded sandstone grains with minor subrounded to rounded pebbles and very minor subangular to subrounded cobbles.
Sorting: Moderately well to well sorted.
Composition: Quartz, feldspar, and lithic grains of mainly quartzite and schist; pebbles and cobbles are mostly acidic volcanic and plutonic varieties.
Structure: Fault block with beds gently dipping to the north.
Thickness: Although thin within area, said to be about 2,400 feet thick to the south (Vedder, 1970, p. 16).
Contact relations: It is in fault contact with other formations in the area; however, to the south the contact with the underlying Vaqueros Formation is gradational and the contact with the overlying Los Trancos Formation is gradational and interfingered.
Age and fossils: Middle Miocene; elsewhere an abundant fauna includes *Balanus, Lyropecten crassicardo, Turritella ocoyana topangensis, Turritella temblorensis, Amusium lompocensis* Arnold, and *Pecten vanvlecki* Arnold.
Distribution and correlation: Exposed in a single fault block immediately west of the Shady Canyon fault along the south margin of the area. Correlated with part of the undifferentiated Topanga Formation elsewhere in Orange County.

ENGINEERING FEATURES

Unified soil classification: Mainly SM with some SC and ML.
Natural dry density: Sandstones range from about 105 to 130 pcf; siltstones range from about 100 to 120 pcf.
Permeability: Moderately low to moderate.
Porosity: Moderately low.
Ease of excavation: Moderate to difficult.
Slope stability: Good.
Fabric: Poorly developed; massive, and thick bedded.
Expansivity: Low.
Erodibility: Moderately low to low.

USE POTENTIAL

Mineral deposits: None.
Fill materials: Good. Suitable for pervious fill. Hard sandstone can be used for riprap.
Waste disposal sites: Not suitable for waste disposal sites because of excavation difficulty.
Ground-water aquifer: Poor due to moderately low permeability and porosity.

DIABASE INTRUSIVES (Td)

TERRAIN FEATURES

Topographic expression: The large intrusive bodies form rounded hills with no rocky outcrops except on the southern edge of the intrusion in Turtle Rock Hills. The smaller dikes form sinuous subdued areas often bordered by blocky or jagged rims of hard sandstone.

Vegetation: Grass, occasional shrubs.

Approximate natural slope angles: In large bodies up to 35°. The large Turtle Rock Hills intrusive mass forms a steep rocky bluff at its south margin.

Slopewash development: Areas of sufficient areal extent form moderately thin slopewash.

Topsoil development: Moderately thick clay loam or dark clay topsoil. Weathering is intensive and fairly deep; some of the large intrusions exhibit deep spheroidal weathering.

LITHOLOGIC FEATURES

Type and color: Diabase dark to medium gray, olive-gray and dark greenish-gray when fresh; pale to moderate brown, pale to moderate yellowish-brown, light olive-gray, and grayish olive when weathered.

Bedding: —

Induration: Poorly indurated in deeply weathered zones; hard when fresh.

Angularity: —

Sorting: —

Composition: Pyroxene diabase.

Structure: Vertical to subvertical dikes and flat to moderately steep dipping sill-like bodies. Boundaries of some intrusions often irregular and enclosing masses of adjacent formation. Occasional spheroidal weathering seen near base of weathered zone.

Thickness: From a few feet to several hundred feet. Largest width of dike is about 1000 feet; the largest sill is more than 150 feet thick.

Contact relations: Intrusive and often faulted; minor local baking effects.

Age: Diabase intruded most of the bedrock units in the area. Most are probably post Topanga; probably of Middle Miocene age. (Vedder *et al.*, 1957).

Distribution: Sills and dikes of diabase scattered over most of the bedrock area.

ENGINEERING FEATURES

Unified soil classification: Weathered material SC, SM-SW, and CL.

Natural dry density: Fresh material about 175 pcf.

Permeability: Low in weathered diabase; fresh diabase impermeable. Shear zones may provide avenues for water penetration.

Porosity: Moderately low, possibly moderately high in weathered zones.

Ease of excavation: Intermediate to easy in weathered zones. Possibly difficult in unweathered zones.

Slope stability: Good; surface creep on slopes with thick soil may be a problem.

Fabric: Commonly jointed and fractured, locally sheared.

Expansivity: Fresh diabase nonexpansive. Weathered material highly(?) expansive. Soils developed on diabase are highly expansive.

Erodibility: Moderately low in weathered material; low in fresh diabase.

USE POTENTIAL

Mineral deposits: None.

Fill materials: Weathered diabase suitable for granular fill. Near surface fresh diabase is suitable for riprap.

Waste disposal sites: Poor due to probable difficulty in excavation below surface weathered zone.

Ground-water aquifer: Poor due to limited areal extent and low permeability and porosity.

VAQUEROS FORMATION (Tv)

TERRAIN FEATURES

Topographic expression: Moderately rounded to well-rounded hills dissected by few ravines.

Vegetation: Generally consists of grass with scattered shrubs, due to periodic clearing. Uncleared slopes support thick chapparal and cactus.

Approximate natural slope angles: Generally less than 26°; occasionally up to 36°.

Slopewash development: Thin to moderately thick. Rarely more than 6 feet thick.

Topsoil development: Generally less than 2 feet of sandy loam. Shaly horizons develop thick clay loam soils.

LITHOLOGIC FEATURES

Type and color: Marine. Pale yellow-brown to dusky yellowish-green interbedded siltstone, sandy siltstone, mudstone, and shale. Very light gray to pale yellowish-gray coarse sandstone and minor conglomeratic sandstone near base of unit, north of Sand Canyon Reservoir. Gray coquina beds and calcareously cemented sandstones common.

Bedding: Massive to thick bedded, except for occasional thin bedded shales.

Induration: Moderate to well indurated; calcareous sandstone very well indurated. Siliceous sandstones bordering some diabase dikes are also very well indurated.

Angularity: Sandstone grains angular to subangular. Conglomeratic sandstone clasts rounded to well rounded.

Sorting: Poorly sorted sandy siltstones and sandstones.

Composition: Sandstones arkosic; apparently chiefly derived from tonalite, siliceous metavolcanic and metasedimentary rocks of the Santa Ana Mountains. The northernmost outcrops of Vaqueros immediately east of Sand Canyon Wash expose some Sespe-like sandstones (see Sespe Formation).

Structure: Extensively faulted in gently to moderately dipping and gently folded blocks. General structure resembles a faulted anticline and syncline plunging northwest. The anticlinal axis trends along Sand Canyon; the synclinal axis is generally defined by the fault crossing Laguna Canyon.

Thickness: The upper contact is not exposed in the area but as much as 2000 feet may be exposed in the Turtle Rock Hills.

Contact relations: Generally conformably overlies the Sespe Formation except in the southern part of the area where there is an apparent angular unconformity between the Vaqueros and Sespe Formations. Upper contacts not exposed in area but are gradational elsewhere (Yerkes *et al.*, 1965, p. 32).

Age and fossils: Early Miocene. Abundant shallow marine fauna found in coquina beds in most sections. Includes *Turritella inezana, Rapana vaquerosensis imperialis, Balanus,* and *Ostrea.*

Distribution: Exposed exclusively east of the Shady Canyon fault, and there underlying more than half of the bedrock area.

ENGINEERING FEATURES

Unified soil classification: SM, SC, and SW with some ML and CL.

Natural dry density: Approximately 100 to 125 pcf.

Permeability: Moderately low to low except for rare highly permeable sandstones.

Porosity: Moderate to low.

Ease of excavation: Easy to intermediate. Occasional cemented sandstones and coquina may be difficult.

Slope stability: Generally fair. Poor in shale and on dip slopes. Several landslides occur within the area mapped as Vaqueros Formation. In the quadrangle to the south where the topographic relief is generally much greater, this unit is one of the most landslide prone in that area. (Tan and Edgington, 1976).

Fabric: Moderately well developed by small joints. Shearing common near faults.

Expansivity: Moderate in shale horizons. Some soils highly expansive, most are moderate.

Erodibility: Moderately low.

USE POTENTIAL

Mineral deposits: None.

Fill material: Fair to poor. Clayey horizons may be suitable for impervious fill, sandy horizons for pervious fill.

Waste disposal sites: Fairly well suited for Class II and III sites due to intermediate to easy excavation and low to moderately low permeability of siltstones.

Ground-water aquifer: Generally poor due to low permeability.

SESPE FORMATION (Ts)

TERRAIN FEATURES

Topographic expression: High relief areas with sharp crested ridges, except for less resistant strata found in the upper part of the unit. These form small areas of low rounded hills.

Vegetation: Generally thick brush cover with some grassy areas.

Approximate natural slope angle: 10° to 20° in most areas; less than 10° in areas underlain by less resistant strata.

Slopewash development: Generally thick. Areas underlain by sandstone develop thick sandy deposits; areas of clayey strata develop thick dark, highly plastic slopewash.

Topsoil development: Sandstones develop little residual soil. Can be thick on clayey strata.

LITHOLOGIC FEATURES

Type and color: Nonmarine. Pale yellowish-gray to very light gray, coarse sandstone and conglomeratic sandstone, medium to coarse clayey and silty sandstone, and red and green sandy claystone and siltstone. Thick claystone-siltstone horizon commonly occurs immediately below contact with overlying Vaqueros Formation.

Bedding: Moderately bedded sandstone with crossbedding common. Claystones and siltstones massive to thick bedded.

Induration: Moderate to poor. Occasional coarse-grained or conglomeratic sandstone well indurated.

Angularity: Sand-sized grains subangular to subrounded. Conglomerate clasts rounded to well rounded.

Sorting: Poor.

Composition: Sandstones arkosic with locally abundant biotite. Conglomerate clasts commonly multicolored siliceous porphyry and welded tuffs with light granitic rocks.

Structure: Follows same general structural trend as the Vaqueros Formation in the form of a northwest-trending, faulted anticline and syncline. Some broad, gentle flexures are found in the southern-most exposures.

Thickness: A complete section is lacking in the area. Possibly as much as 1700 feet is exposed along the southeastern margin.

Contact relations: Gradational contact with underlying Santiago Formation. Overlain conformably, and locally unconformably, by the Vaqueros Formation.

Age and fossils: Late Eocene(?) to early Miocene, based on fossils from the overlying Vaqueros Formation in the area and fossils from the underlying Santiago Formation in other areas. No fossils noted.

Distribution: Exposed only east of the Shady Canyon fault in this quadrangle.

ENGINEERING FEATURES

Unified soil classification: SM and SC with some SW, SP and GC in sandstone areas. CL, CH and some ML in claystone and siltstone areas.

Natural dry density: Sandstones range from 105 to 114 pcf, claystones, from 98 to 117 pcf.

Permeability: Moderate to moderately high in sandstones; moderately low to low in claystones and siltstones.

Porosity: Moderately high to moderately low.

Ease of excavation: Moderately easy in sandstones; easy in claystone-siltstone.

Slope stability: Poor on claystone and siltstone horizons. Good to fair on sandstone strata excepting dip slopes. Several large slides occur on dip slopes in sandstone and on claystone-siltstone strata.

Fabric: Moderately poorly developed. Scattered fracturing and shearing occurs throughout unit.

Expansivity: Low in sandstone strata. Moderate and possibly high in claystone-siltstone horizons; soil and slopewash developed from these horizons are highly expansive.

Erodibility: Low to moderately low for sandstones, due in part to a "case hardening" of exposed surfaces. Moderately high to high for claystone-siltstone horizons.

USE POTENTIAL

Mineral deposits: There may be a potential use for conglomeratic sandstones as sources of sand and gravel. At present, the low gravel fraction and high content of fines makes economic use of this material unfeasible.

Fill materials: Sandstone horizons are well suited for pervious fill. A large borrow pit has been excavated in Sespe sandstone immediately west of the Sand Canyon Dam.

Waste disposal sites: Sandstones poorly suited for Class II sites due to high permeability, and poorly suited for Class III due to high erodibiltiy in disaggregated state. Siltstone and claystone horizons too limited in extent to be suitable.

Ground-water aquifer: Sandstone horizons good due to moderately high permeability and porosity and areal extent of exposures.

SANTIAGO FORMATION (Tsa)

TERRAIN FEATURES

Topographic expression: Forms low rounded hills with few bedrock exposures.
Vegetation: Covered with thick brush except in areas cleared for cattle grazing.
Approximate natural slope angles: 10° to 30°.
Slopewash development: Moderately thick slopewash at base of slopes and along gullies.
Topsoil development: Poorly developed thin soils on sandstone; moderately to well developed clayey soils on claystone-siltstone.

LITHOLOGIC FEATURES

Type and color: Yellowish-gray to pale yellowish-brown medium- to coarse-grained sandstone, grayish-green shaly siltstone, and red and green sandy claystone and siltstone.
Bedding: Massive to thick bedded. Occasional crossbedding.
Induration: Moderate to moderately poor induration in sandstones. Siltstones and claystones poorly indurated with some moderately poorly indurated siltstones.
Angularity: Angular to subrounded sand-size grains. Rounded to well rounded gravel-size clasts.
Sorting: Poorly sorted sandstones.
Composition: Arkosic sandstone with minor mica content. Clasts are primarily siliceous plutonic, metavolcanic, and metasediment types derived from the Santa Ana Mountains; some varicolored porphyritic volcanic cobbles are present.
Structure: Several minor faults and shears cut the relatively small exposure. The block is predominantly westerly dipping at a moderate angle.
Thickness: The exposed section represents only a portion of the upper part of the unit. Discounting any faulting which may be obscured by the sediments in Sand Canyon, the exposed section represents about 150 feet of section.
Contact relations: Gradational contact with overlying Sespe Formation. Although the lower contact with the Silverado Formation is not observed in the area, it is known, from other areas, to be a disconformity.
Age and fossils: Eocene; determined by fossils found in localities outside of the study area. No fossils noted in this area.
Distribution: Exposed in small areas on both sides of Sand Canyon Reservoir.

ENGINEERING FEATURES

Unified soil classification: SM and SC with some ML and CL.
Natural dry density: Sandstone will probably range from 105 to 115 pcf and claystones and siltstones from 95 to 120 pcf.
Permeability: Moderate to moderately high in sandstones; moderately low in claystone and siltstone.
Ease of excavation: Easy in most horizons; few moderately indurated sandstones may be moderately easy.
Slope stability: Good on sandstone strata, fair to poor in areas underlain by claystone.
Fabric: Poorly developed.
Expansivity: Low in sandstones, moderate and possibly high in claystones, and moderately low in siltstones. Soil and slopewash developed from claystones are highly expansive.
Erodibility: Moderately high to moderately low.

USE POTENTIAL

Mineral deposits: None.
Fill materials: Sandstone well suited for pervious fill.
Waste disposal sites: Poorly suited for waste disposal sites of Class II or Class III due to high permeability of sandstone and limited areal extent.
Ground-water aquifer: Sandstone strata may provide for limited ground-water storage.

SILVERADO FORMATION (Tsi)

TERRAIN FEATURES

Topographic expression: Varied. Forms both steep hills and gentle rolling areas. Hard sandstone beds leave large blocks standing above the surface.

Vegetation: Varied. Higher hills support thick brush on steeper sides. Lower areas are grassy with a few trees.

Approximate natural slope angles: 5° to 50°, with some antidip slopes near vertical.

Slopewash development: Thin, patchy development.

Topsoil development: Generally thin clay loam or clay soils, sandy siltstones develop a moderate soil cover.

LITHOLOGIC FEATURES

Type and color: Nonmarine and marine, medium- to coarse-grained white to very pale orange or light brown sandstone, silty sandstone and pebbly to cobbly sandstone with minor amounts of interbedded siltstone and claystone. A single bed of white-gray sandy claystone, possibly equivalent to the Serrano clay bed found in the Santa Ana Mountains, was mapped separately as shown on map.

Bedding: Moderately well to well bedded. Normally thick bedded with sandstone crossbedded.

Induration: Moderately well to very well indurated sandstone. Silty sandstone moderately indurated. Several sandstone beds are siliceously cemented and very hard. These occur more often in the northern, intensely faulted area.

Angularity: Sand-sized grains angular to subangular. Pebble and cobble-sized clasts subrounded to rounded.

Composition: Sandstone arkosic with well-weathered feldspar and locally abundant biotite. Clasts are chiefly siliceous plutonic rocks. Serrano-like horizon of sandy clay contains chiefly kaolinite clay.

Structure: Generally moderately dipping in a west dipping homocline in the south becoming more intensely faulted and sheared to the north forming the core of a faulted anticlinal structure with a north to northwestward trending axis. Outcrops exhibit shear planes and well spaced joints.

Thickness: As much as 900 feet of an incomplete section may be exposed. It is estimated, by subsurface data, to be approximately 1,875 feet thick (Vedder, 1970).

Contact relations: All observed contacts are faults except for the intrusive contact with the diabase dike along the eastern margin. Some baking of the sandstone is evident along this contact.

Age and fossils: Paleocene, as indicated by fossils found in the Santa Ana Mountains (Woodring and Popenoe, 1945) within the lower part of the formation. Some fossil wood fragments were found in a thin bedded silty sandstone horizon.

Distribution: A single, moderately large area, east of the Shady Canyon fault.

ENGINEERING FEATURES

Unified soil classification: SM, ML, CL with some SC.

Natural dry density: Sandstone about 100 to 115 pcf.

Permeability: Moderately low to moderately high.

Porosity: Generally moderately high.

Ease of excavation: Moderately easy except for well indurated sandstone beds which will be difficult.

Slope stability: Generally good. Rockfall occurs on steeper hill sides.

Fabric: Softer silty sandstone horizons have little fabric. The more resistant sandstone beds have well developed joint patterns as well as shear systems.

Expansivity: Low to nonexpansive.

Erodibility: Low to moderately low.

USE POTENTIAL

Mineral deposits: A clay bed much like the Serrano clay horizon in the Santa Ana Mountains is exposed discontinuously for about one mile in the quadrangle. Its location is noted on the map.

Fill materials: The softer sandstones and silty sandstones are suitable for fill material; the hardest sandstone beds may be suitable for riprap.

Waste disposal sites: Not suitable for disposal sites due to difficulty in excavation of sandstones and moderately high permeability of some horizons.

Ground-water aquifer: Moderately poor over-all; some of the softer sandstone beds may provide some ground water avenues.

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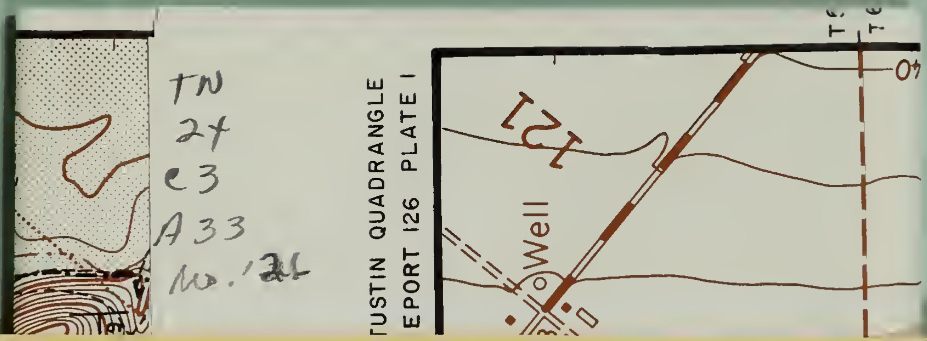
TUSTIN QUADRANGLE
EPORT 126 PLATE 1



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THOMAS E. GAY JR., ACTING STATE GEOLOGIST

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S1/2 TUSTIN QUADRANGLE
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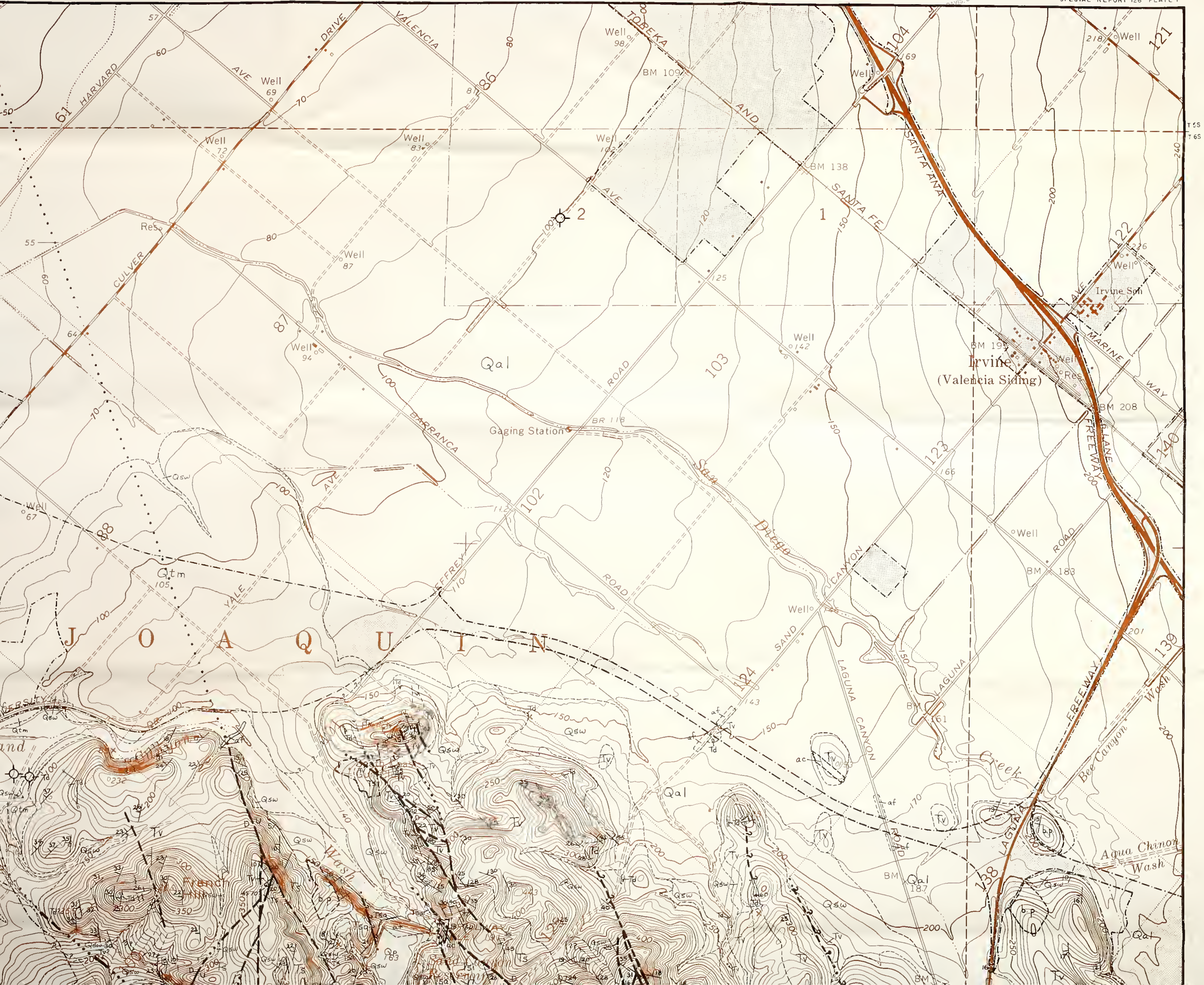


EXPLANATION

SURFICIAL UNITS *

QUATERNARY	Holocene	af	Artificial fill
		Qal	Alluvium
		Qp	Pond deposit
		Qsw	Slopewash debris
	Pleistocene	▨	Landslide deposit (Qls in cross section)
		Qtr	River terrace deposits
		Qtm	Marine terrace deposits

BEDROCK UNITS *

TERTIARY	Late Pliocene	Tn		Niguel Formation
	Late Miocene	Tm		Monterey Formation
				Intrusive Rocks *
		Td		Diabase sills and dikes
	Middle Miocene	Tt	Ttp Ttl Ttb	Topanga Formation; Ttp-Paularino member; Ttl-Los Trancos member; Ttb-Bommer member.
	Early Miocene	Tv		Vaqueros Formation
	Oligocene	Ts		Sespe Formation
	Paleo-cene Eocene	Tso		Santiago Formation
		Tsi		Silverado Formation

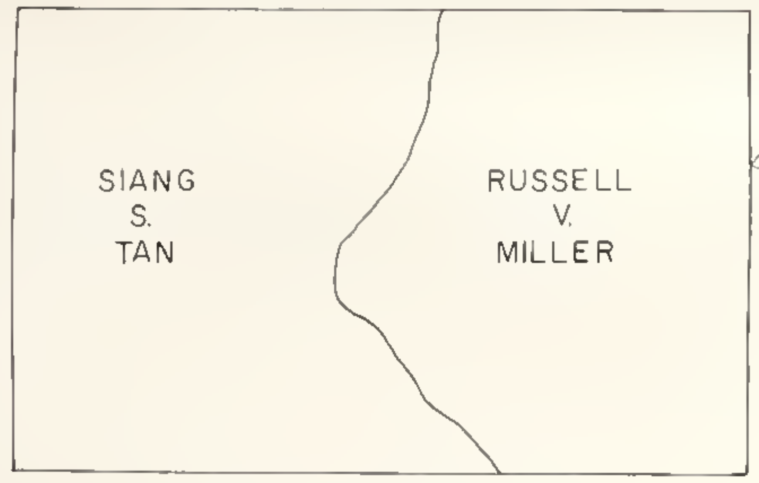
* See text for detailed description

SYMBOLS

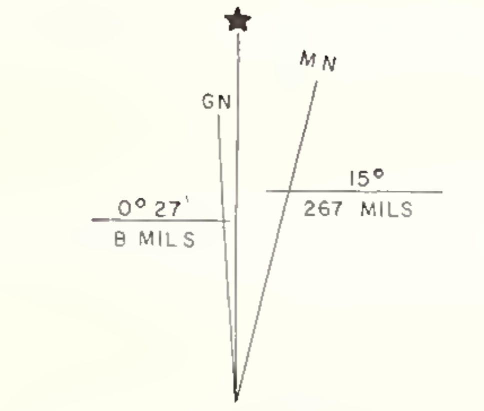
TOPOGRAPHIC BASE MAP BY THE U.S. GEOLOGICAL SURVEY 1965
ENLARGED FROM 1:24,000 SCALE

GEOLOGY OF THE SOUTH HALF OF THE TUSTIN QUADRANGLE ORANGE COUNTY, CALIFORNIA

By
Russell V. Miller
and
Siang S. Tan



AUTHOR INDEX OF MAPPING
S 1/2 TUSTIN QUADRANGLE



UTM GRID AND 1965 MAGNETIC NORTH
DECLINATION AT CENTER OF SHEET

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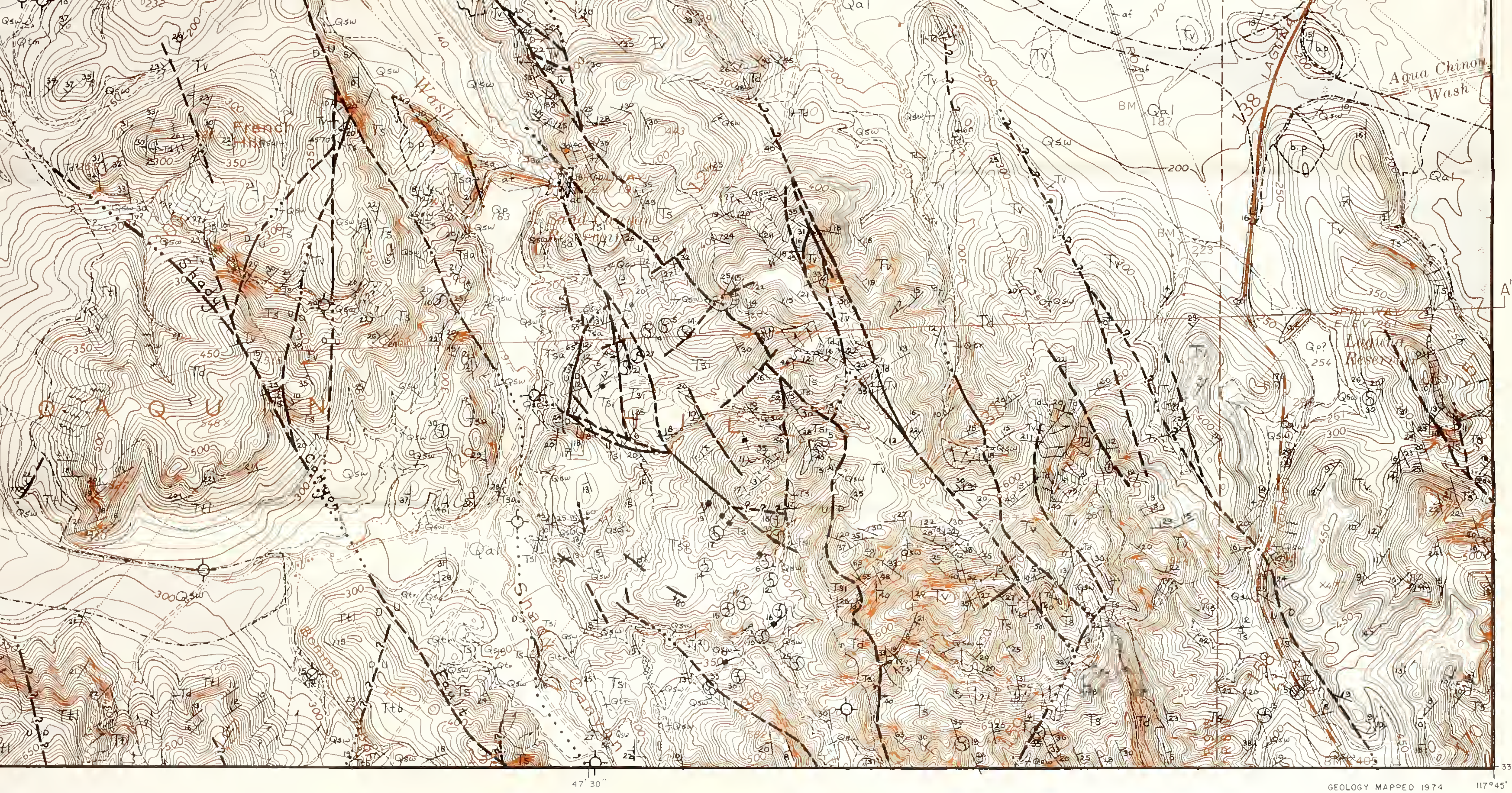
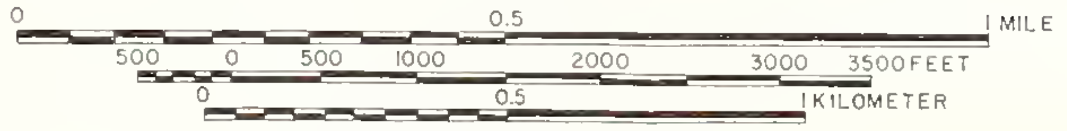


GEOLOGY MAPPED 1974

SOUTH HALF OF THE TUSTIN QUADRANGLE
ANGE COUNTY, CALIFORNIA

By
Russell V. Miller
and
Siang S. Tan

SCALE 1:12,000



CONTOUR INTERVAL 10 FEET
DOTTED LINES REPRESENT 5-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

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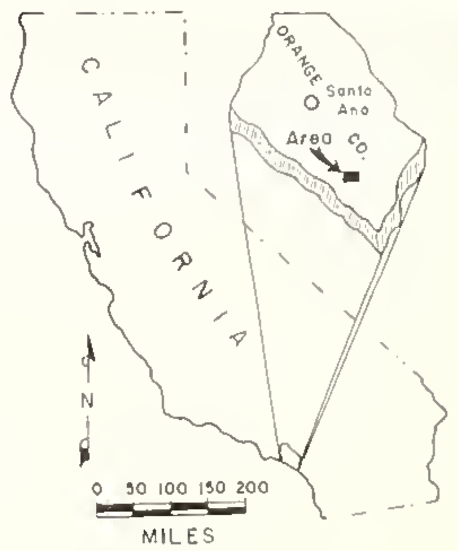

INDEX MAP

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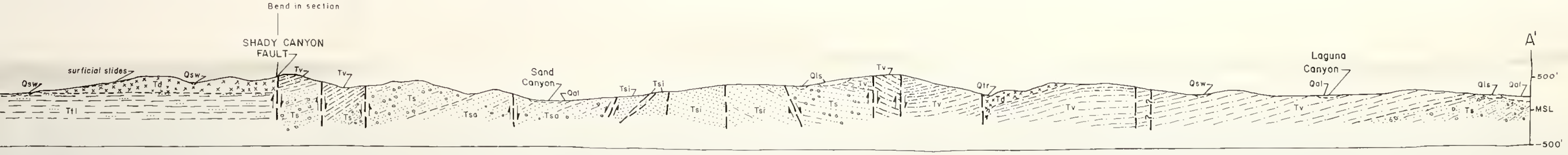

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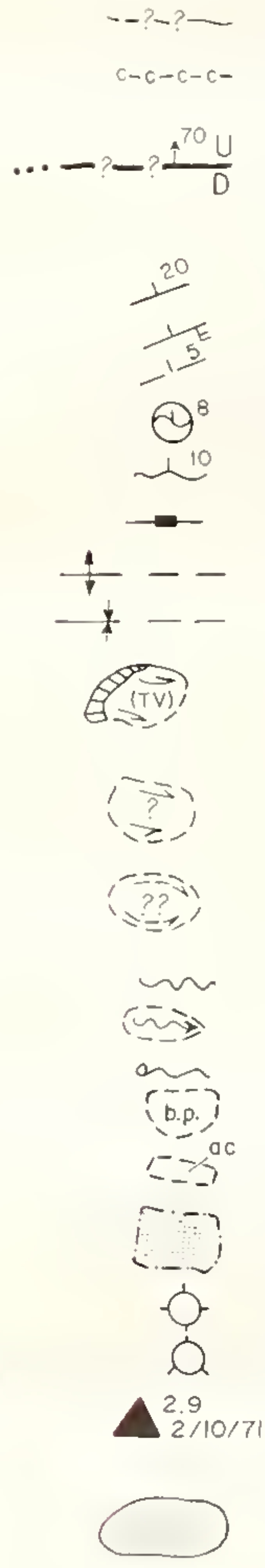

Contacts; dashed where approximated; queried where inferred, solid where located with certainty

Denotes clay bed in the Silverado Formation

Faults, dotted where concealed under younger deposits, dashed where approximated, queried where inferred; solid where certain; arrow indicates dip; U=upblock relative to downblock-D (subsurface faults in the Tustin plain are based on unpublished exploratory oil boring data).

Attitude of bedding

Attitude taken from excavation no longer open

Approximated attitude of bedding

Crossbedding and general dip

Crumpled or undulatory bedding and general dip

Trend of vertical open joint pattern taken from aerial photograph

Axis of anticlinal fold; dashed where approximated

Axis of synclinal fold, dashed where approximated

Bedrock landslide, dashed where boundary approximated; scarp area hachured, bracketed formation designation indicates major geologic unit within landslide.

Probable landslide

Possible landslide.

Surficial creep

Surficial landslide.

Spring or seep.

Borrow pit or borrow area

Artificial cut.

Developed area with undelineated artificial cuts and fills.

Exploratory boring drilled for petroleum

Water well

Earthquake epicenter, magnitude and date. Location accuracy: ±5 km. (Hileman, Allen and Nordquist, 1973)

Area where peat may occur or has been found in the subsurface (Evans, 1974)

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